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Alkali studies, II.

Wyoming experiment station. Bulletin no. 391



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Agricultural College Department.

WYOMING EXPERIMENT STATION,
LARAMIE, WYOMING.

BULLETIN NO. 39.

DECEMBER, 1898.

ALKALI STUDIES, II.

BY E. E. SLOSSON AND B. C. BUFFUM.

Bulletins will be sent free upon request. Address: Director Experiment Station, Laramie, Wyo.

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Alkali Investigations.

E. E. SLOSSON.

THE CHARACTER OF WYOMING ALKALI.

The Experiment Stations are supported for the purpose of scientific research in the problems of agriculture and they are located in different states in order that each station may study, at close range, the conditions of the region that surrounds it. From its location the chief problem of the Wyoming Station has been given to it by nature, the study of aridity, and as fast as possible the work of the Station has been concentrated on this subject.*

The chief difficulties in the way of agriculture in the arid region are two, the insufficient supply of water and the accumulation of soluble salts, known as alkali. The second of these is a consequence of the first. Where watering is done by rain, pure water is added to the soil and drained off underneath, carrying with it the soluble salts of the soil. In irrigation, water containing salts is added to the soil and pure water evaporated from the surface. It was shown in Bulletin No. 24 that half a ton of alkali was added to each acre of the Sheridan Farm every year by irrigation and the land became completely useless until it was drained.

Samples of alkali from all parts of the State have been analyzed and the complete analysis will be published in the next annual report. It will be sufficient to give here the

*For a summary of the publications of the Station on this subject, see Eighth Annual Report, 1898. pages 15-50.

general result. Almost all the alkali of the State consists of three salts in varying proportions, sodium sulphate (Glauber's salt), magnesium sulphate (Epsom salt) and sodium chloride (common salt). The "black alkali," sodium carbonate, is fortunately very rare as it is much more injurious than the other salts. Analysis of the soils of the State shows that the percent of soluble salts or alkali is usually small, often extremely so, and it is only its accumulation at the surface that causes damage. On the other hand the small amount of water in the soil makes the alkali more injurious than if more diluted, for it must be remembered that it is not the total quantity of alkali in the soil but the strength of the alkali solution that is of importance. For example, if the soil contains 10% of water about 3% of common salt is required to form a saturated solution, but if there is only 5% of water half that amount of salt will produce the same effect and any larger amount is no worse. On unirrigated land the water content is mostly between these limits. (Bulletin No. 35.)

In many parts of the state the alkali salts are not mixed together and distributed through the soil, but are collected in large beds of single salts often very pure. Near Laramie there are beds of sodium sulphate, near Rock Creek of magnesium sulphate and near Green River of sodium carbonate (sal soda) of many acres in extent and several feet in thickness. Many theories have been advanced as to the origin of these "alkali lakes," mostly based on the assumption that they must have been made from the decomposition of rocks containing the same salts. Since there are no rocks in the vicinity whose products of decomposition at all resemble the alkali, the advocates of this theory have been obliged to construct hypothetical rocks for the purpose. If, however, we remember that the salts deposited from solution depend on the proportions, temperature and concentration, and need not be at all the same as the salts dissolved, we

can account for the alkali beds without taking into consideration the origin of the salts. It is enough for us to know that all the spring and river waters of the state contain the necessary elements and the problem is merely to separate them into the forms that are actually found.

The salts in the alkali lakes can not be regarded as of any certain composition. They become liquid, that is dissolve in their water of crystallization on a warm day or are dissolved by the addition of rain water and when deposited by cooling or evaporation it would be very improbable that the same forms should reappear in the original proportion. Then too the addition of drainage water containing more salts must change the equilibrium and cause a rearrangement to form new salts. This may account in part for the widely variant analyses that have been published, and observations at different seasons of the year show startling changes. Sometimes the lake is fluid, at others solid. Sometimes it is a bed of large clear crystals of sodium sulphate decahydrate; sometimes the white anhydrous sodium sulphate covers the surface. The phenomena can be watched very prettily by dissolving the salts in a beaker of water in such proportions and concentrations as to be in unstable equilibrium. If the temperature of the room varies considerably the form, size and composition of the crystals will often be very different.

The salts contained in natural alkali are remarkable for the number of their phases. We have in the natural waters of the State from which the alkali is deposited, the bases sodium, calcium and magnesium, and the acids carbonic, sulphuric and hydrochloric. There are also sometimes present the bases potassium, aluminum, iron and lithium, and the acids nitric, boric, silicic, phosphoric and reduced sulphuric acids, but only in such small quantities that they do not play any important part in the formation

of the alkali deposits. Evaporation of a solution containing the above six factors might form nine simple salts and a great number of double salts and hydrates, besides mechanical mixtures of all these in any proportion.

It would be impossible to prove what the conditions were under which beds of pure salts like the Wyoming alkali lakes were found, because the concentrations, proportions and temperatures at the different stages of formation are all unknown and it is evident that theoretically the same result could be obtained by many different reactions. Since none of the compounds are absolutely insoluble and since nature has unlimited time and reagents, we must regard any reaction as reversible, however completely it may go in one direction in the laboratory. But it is not impossible that a consideration of the simpler reactions of these factors may throw some light on the probable way in which pure salt deposits have been formed. Starting with a solution such as our natural waters containing the bases calcium, magnesium and sodium and the acids carbonic, sulphuric, and hydrochloric, the most insoluble compound possible would be first precipitated. This is calcium carbonate or a mixture of calcium and magnesium carbonates forming beds of limestone or dolomite. Calcium carbonate is, however, much more soluble in the presence of other salts than we usually think and magnesium carbonate is found in large amounts in water of the state containing much sodium carbonate. The calcium sulphate would next be deposited in the form of gypsum. Beds of gypsum of great thickness exist in many parts of the state, as at Red Buttes, where plaster of Paris has been made for many years, and it is abundant in most of the soils. In the Laramie Plains gypsum was found at intervals in boring the University artesian well to the depth of a thousand feet. If, as is generally assumed, sodium was originally extracted from the rocks in the form of carbonate, the absence of this salt in most of

the state could be accounted for by the well known reaction between sodium carbonate and calcium sulphate to form sodium sulphate and limestone. This has been used in practical agriculture on the advice of the California Station to eliminate the more injurious black alkali or carbonate. In parts of the state where sodium carbonate is found, as at Green River and Johnstown, gypsum is of course absent, or nearly so.

If now we regard both the calcium and the carbonic acid as completely precipitated, we have left as possible compounds magnesium chloride and sulphate and sodium chloride and sulphate. Of these, magnesium chloride is by far the most soluble at ordinary temperatures and would therefore be the last salt deposited and the first washed out from an alkali bed. In all the alkali and waters analyzed in the state the sulphates are in large excess over the chlorides, so we may regard magnesium chloride as practically absent and the salts formed would be only magnesium sulphate, sodium sulphate and sodium chloride. Analysis shows that almost all of the alkali of the state consists of these three salts in varying proportions. There are beds of pure magnesium sulphate and sodium sulphate, but so far as I am aware there are no deposits of sodium chloride. Brines exist but do not form beds.

These three salts are about equal in solubility at ordinary temperatures and on complete evaporation would be deposited together, which is usually the case. But their relative solubility is greatly changed by a variation in temperature, as the sodium sulphate is much more soluble in warm than in cold water, while with sodium chloride there is little difference, so the fall in temperature in a single night, which is often great in the arid region and high altitudes, would precipitate a thick layer of crystallized sulphate which would not dissolve again the next day. In

many of the strong alkali lakes this can be observed directly. In cold weather the bottom is covered with a thick bed of pure sodium sulphate, above which is a saturated solution containing much chloride. In warm weather part of the bed goes into solution again. In winter Great Salt Lake throws up on the shore sodium sulphate crystals in banks looking like snow drifts. The magnesium sulphate beds might have been formed in a similar way.

It is possible by this system of simple reactions to explain the alkali deposits, although it is evident that they can be theoretically accounted for in other ways, and it is not necessary to assume that similar deposits have an identical origin. All that is intended is to show how from a dilute solution of many substances, such as ordinary spring or river water, the salts actually found could be formed and not the many others theoretically possible. It is not necessary to assume, as many have done, that the original rocks corresponded in composition to the salts left in evaporation of their leachings. With the conditions that prevail in Wyoming, an annual evaporation about five times as great as the rainfall, a porous soil and scanty vegetation, such an accumulation and differentiation of salts is quickly accomplished. One can start with a good soil and irrigate it with water of ordinary composition and in a few years crystals of pure sodium sulphate may be picked off the surface. This experiment has unfortunately been repeated on a great many acres.

The principal source of the alkali is not, however, the water used in irrigation, but the beds of soluble salts that are deep in the soil. As soon as water is put on the land these salts are drawn to the surface by evaporation. The fact that the soils of the valleys are saturated with alkali ought to be taken into consideration in the proposed establishment of reservoirs. If these are of wide extent the

great evaporation of these regions would concentrate the water and so increase the per cent of alkali it contains. To this the alkali leached from the surrounding soil will be added and there is danger that water so stored would become injurious rather than beneficial to the land which received it.

ABSORPTION OF WATER FROM ALKALI SOLUTIONS BY SEEDS.

Before we can hope to do much to mitigate the injurious effects of alkali on plants we obviously must know what that effect is. How does the alkali limit the plant? Although it will be many years before any complete answer can be given to that question, yet the study of the subject by the Station has cleared up some of the simpler points. For the simplification of the problem it was divided into two parts, the effect of alkali on the germination of the seed and its effect on the growth of the plant. Only the first part of the work will be made public here.

The effect of alkali on the germination of seeds depends on three things, the kind of seed, the kind of alkali, and the concentration of the alkali solution. Sometimes the seeds in alkali solution are killed, sometimes they germinate but very slowly, sometimes they germinate more quickly as compared with those in pure water. The usual result is that the seeds are delayed in germination for a long time. Now in Wyoming the season is too short anyway, and even a few days' delay will make the difference between a crop and a failure.

A necessary preliminary to germination is the absorption of water, and it seemed likely that the retarding effect of the alkali on the germination was due to its hindering the seed from absorbing the water it needed. Experiments showed that this was the case, and work on this line has

been carried on in the chemical laboratory for about three years now. The technical details will be published in the annual report of July next, but a table showing the results of one of the experiments is here given to show how such work is carried on. Wheat was the seed experimented upon in this case and an equal weight of it was put into solutions of the common alkalies of various strengths, pure water, and a solution of sugar introduced for comparison. It was found that the absorption of water was influenced not by the kind of alkali or the strength of the solution but purely by the osmotic pressure. Osmotic pressure is not generally understood and in fact is a comparatively new conception in science, but it is easy to explain what it means. In this case it simply means that the water passes through the little coatings in the seed openings more easily than the particles of salt, and consequently a seed will take up water more rapidly if no salt is present. To give a rough illustration, a pump supplying city water works will get more water through the screen of the intake pipe if the holes of the screen are not partly clogged with sand and drift wood. In this experiment, the solutions of sugar, sodium sulphate, magnesium sulphate, and sodium chloride were so made as to have the same osmotic pressure, and it will be seen from

Amount of Water Absorbed by Wheat from Salt Solutions.

No.	Solution of	Per cent of salt.	Osmotic pressure, atmospheres.	PER CENT WATER ABSORBED BY WHEAT.											
				12 hours.	24 hours.	36 hours.	48 hours.	60 hours.	72 hours.	84 hours.	96 hours.	108 hours.	120 hours.	132 hours.	144 hours.
1.	Pure Water	0	0	331	426	492	516	546	557	563	601	601	617	623	623
2.	Sugar	1.43	1	334	432	493	513	543	552	582	598	608	614	620	617
4.	Magnesium sulphate . . . . .	.34	1	314	401	463	493	521	547	567	577	596	606	608	602
6.	Sodium sulphate . . . . .	.24	1	321	416	478	488	532	544	577	583	601	619	617	607
8.	Sodium chloride . . . . .	.12	1	340	419	495	500	518	537	569	579	583	591	593	603
3.	Sugar	14.30	10	263	279	418	442	450	460	467	478	481	481	481	479
5.	Magnesium sulphate	3.94	10	312	384	433	455	453	469	479	489	489	489	487	487
7.	Sodium sulphate	2.66	10	297	383	436	440	451	459	463	479	483	486	483	492
10.	Sodium chloride	1.39	10	315	397	443	449	466	470	472	472	476	474	482	500

the table that the wheat absorbed just about the same amount of water from each of these in the same length of time. Sodium carbonate ("black alkali") acts differently, for when it is strong it attacks and destroys the seeds themselves. Some seeds, too, give quite different results. Beans absorb the same amount of water when put into a saturated solution of common salt as they do when put into pure water. The dissolved salt apparently passes into the bean as readily as the water and destroys its power of germination. Rye is intermediate between wheat and beans in this respect.

To decide the question whether the absorption of water is physical or physiological, comparative tests were made between living seeds, and seeds in which the power of germination had been destroyed by age, heat, or exposure to formaldehyde vapor. No difference between the living and dead seeds has been yet observed, so it appears that water is drawn into the seed purely by such physical forces as surface tension and osmotic pressure. It does not appear that the salts mentioned, except sodium carbonate, exert any poisonous influence on the wheat. It germinates readily when removed from the alkali solutions and put under favorable conditions.

The absorption of water is retarded and diminished by the presence of salts in the water, but not prevented. This is due to the fact that the seed allows the salt to pass into it though not so readily as the water. The volume of the swelled seed and the amount of salt they contain has been determined and it appears that in strong solutions enough salt is absorbed to make the solution inside the seed nearly the same strength as that outside. In this way the resistance to absorption of water due to osmotic pressure is diminished. The same means of obtaining water from a strong salt solution is probably used by such plants as the salt sage, which contains a large amount of mineral salts. This has

the double advantage of aiding the plant to draw water from the soil and to keep better what water it has, because the salts dissolved in the sap lessen the evaporation.

The experimental work here outlined is being applied to plants as well as seeds, with the hope of finding out why it is that certain plants thrive in soil containing much alkali and little water, while others, sometimes of the same genus, will die under these conditions. Experiments on low forms of life show that they can be made immune to the deleterious effects of a very great osmotic pressure by slow changes and selection, and this suggests the possibility that the same can be done for higher plants, and useful vegetation be grown to cover the acres now given over to greasewood or samphire.

Alkali Investigations.

B. C. BUFFUM.

FIELD EXPERIMENTS.

The experiments or lines of investigation under way in the field were outlined in Bulletin No. 29 of this station. While it can not be said that any of this work has been completed, some results have been obtained which are of interest. The productive area of the Station Farm is continually being encroached upon by the rise of alkali salts on the lower parts of the land. At the same time the greatest care has been exercised in our irrigation. It can not be laid to over-irrigation, or the careless handling of the water used. We know of no way to effectually prevent the accumulation of alkali salts upon low lands which have no drainage outlet. It is possible to irrigate land which has considerable slope without allowing any appreciable amount of waste water to escape, but, unless the land is level, some of the water finds its way through the soil or subsoil down the slope, carrying a quantity of the soluble salts with it. If there is good drainage the salts are washed out of the soil into streams and carried off. Where there is no outlet of this kind a reservoir is formed in which the salts accumulate just as water collects in a lake bed. As more of the salts are washed from the higher ground the accumulation increases and more land is added to the unproductive alkali waste.

Where the process of leaching has not begun the salts naturally occur distributed through the soil in compara-

tively small quantities. Small amounts of these salts are beneficial, either acting directly as plant food or indirectly aiding in the process of plant nutrition. The fact that the soluble portion of our soils has not been leached out and carried away by excessive rainfall accounts for such lands being almost if not quite as rich and lasting as the soils along the Nile, which receive an annual supply of leachings and sediment from the head waters of that stream. However, when our lands are brought under irrigation and cultivation there seems to be no way of keeping the soluble salts scattered through the soil as they were originally. When water is applied they move downward. By the percolation of water through the soil, the salts are carried from one place to another, accumulating where the water accumulates. When the water evaporates from the surface the salts in solution are left behind and more water coming up from below continually adds its freight of salts, leaving them where they can do the most damage to crops. This simple principle of the movements of alkali salts in the soil along with the water furnishes the key to any preventive treatment which must be along one of the following lines:

1. Irrigation with water free from salts.
2. Preventing seepage.
3. Draining the water from below.
4. Cultivating or treating the surface in such a way as to prevent evaporation, which brings the salt to the surface.

Over-irrigation and the lack of most intelligent and thoughtful management brings about rapid and wide-spread destruction of the most fertile lands. Good natural or artificial drainage will enable the farmer who properly crops, cultivates, and irrigates his land to prevent any damage from alkali, providing the water with which he irrigates does not bring large amounts of salts to his soil.* But there are places without good, natural drainage where artificial

*For data of the amount of alkali salts actually deposited upon some soils from the water used in irrigation, see Wyoming Station Bulletin No. 24, "Water Analyses.")

drainage will be too expensive for years to come and where alkali is accumulating more or less rapidly. As yet the farmer has no market for his crop of salts and unless he can so treat the land that it will bring some return he is better off without the useless acres upon which the taxes are the same as upon the rest of the farm.

All this discussion leads up to the point I wish to make. Although we may know of no easy or cheap method of reclaiming such lands so all crops will thrive upon them we may make them productive by introducing plants which will grow in the presence of large amounts of alkali salts. Professor Hilgard has accomplished a great deal in introducing alkali resisting plants to cultivation in California. We have been experimenting with such plants for some time and are now able to report upon a few of them.

We have found very few useful plants which will grow where the soil contains so much alkali that an incrustation is formed on the surface. Incrustation of our ordinary white alkali on the surface is usually marked, at least during dry weather, where there is as much as one and one half or two percent of salts in the first two inches of soil. Such an amount of salts will prevent the growth of any of the cereals or of alfalfa. Barley and rye seem to stand more alkali than will wheat or oats. I believe barley, rye, or alfalfa will grow in the presence of as much as one percent of our ordinary white alkali, (sulphates of soda and magnesia), in two inches of surface soil, providing the water level is not nearer the surface than two or three feet. Usually where there is so much alkali as this, which has accumulated from irrigation above, the water comes near the surface, leaving the soil saturated most of the time. Where this occurs less than one-half of one percent of salt along with the water is fatal to such crops. Upon soils containing about two percent of salts in the first two inches we have tried, without success, rye, wheat, barley, oats, alfalfa, and Russian sunflowers.

Brome grass and red top have been partially successful. Our experiments with them have not been extensive enough to reach final conclusions.

The following alkali-resisting plants need special mention.

SALT SAGES OR SALT BUSHES (Species of *Atriplex*).

Just now many enterprising seedsmen are advertising the "Australian Salt Bush," (*Atriplex semibaccatum*), urging farmers to purchase the seed for sowing upon their alkali lands. It has been very successful in California, where it produces large yields of forage. However, it is a warm climate plant and does not succeed in Wyoming. We have given it careful trials at Laramie, Lander, and Sheridan. At Laramie it only made a small growth the first season. At Sheridan its growth was thrifty the first summer. The Superintendent of the Sheridan Farm, Mr. Lewis, stated that he had difficulty saving the plants from destruction by what he called "the common beet bug," or "the long gray potato bug."* By a liberal use of Paris green, the insects were destroyed. The plants made a spreading growth, almost covering the ground by the time of frost. None of the plants lived through the winter at any of the places they were tried.

There are a number of species of *atriplex*, closely related to the Australian Salt Bush, found native in the State, which grow in alkali lands. Some of them are of much importance as forage plants. The more promising of these are being studied by our Botanist, who is co-operating with this department in attempting to introduce them into cultivation and determine their value for wider distribution.†

*This insect is one of the Blister Beetles (*Epicauta* sp. ?). It has done considerable damage to beets and potatoes in parts of the state, especially in Sheridan and Crook counties.

†A valuable contribution to our knowledge of the forage plants which grow in the alkali soils of our state is contained in Bulletin No. 13 of the Division of Agrostology of the United States Department of Agriculture, entitled "The Red Desert of Wyoming and Its Forage Resources," written by Professor Aven Nelson of this Station. In this bulletin the salt sages and other plants found growing in alkali places are discussed, with data relating to their value as food for range stock and suggestions as to usefulness of certain species if brought under cultivation.

Plants of this character, which take up large amounts of the alkali salts, will naturally aid in removing the salt from the soil with the crop. Stockmen have long appreciated this property of the salt sage, regularly making use of it as food for their range stock, to avoid the necessity of purchasing common salt for them.

ENGLISH RAPE.

Dwarf Essex Rape was planted upon the Experiment Farm two seasons, being sown upon strong alkali soil which would not produce grain or alfalfa. In 1894 a rather thin stand was obtained. The soil was very damp all summer. About the first week in August the rape began to make a rank growth. When cut on September 3 it yielded at the rate of a little over fourteen and one-half tons of green fodder per acre. In 1896 rape planted on strong alkali ground also made excellent growth. Rape is attracting much attention as a soiling crop or as forage, especially for sheep. While it is an annual plant it may prove of value upon alkali soils in the state.

BOKHARA OR WHITE SWEET CLOVER.

(*Melilotus alba*.)

At Laramie and at Sheridan sweet clover has made large growth upon strong alkali soils. Unfortunately it seems to be of little or no value unless it be as a honey plant for bees, though I have been told it is cut and baled for cattle food in parts of Utah. Heretofore I have warned our farmers not to plant this clover on account of its spreading to places where not wanted and becoming a troublesome weed, where allowed to ripen its seed.* Recent experiments indicate that it may be of some value for alkali land, to improve the soil before planting other crops. In 1897 an alkali plat was

*See Wyoming Station Bulletin No. 16, page 236. In this connection Professor Hilgard has told me that in California, where sweet clover became a weed in wheat fields, millers refused to buy the wheat, as it became tainted with the strong, peculiar odor of the clover seed and complaint was made that the flour from such wheat made gingerbread. If planted for any purpose it should not be allowed to spread, but all plants should be cut when in bloom to prevent the production of seed. It is a biennial, producing its seed the second year and then dying.

planted to sweet clover. This season, 1898, at the time it was in blossom it had produced 18.4 tons of green tops per acre, and was plowed under for green manure. The average height of the plants was 5.2 feet and computed as dry hay the yield was over four and one-half tons per acre. It was difficult to plow under so large a crop. Like other leguminous crops this clover takes nitrogen from the air by means of the little tubercles on the roots. The roots of those plants which we examined were literally covered with these tubercles, which indicates that sweet clover may prove of value as a nitrifying agent. Adding nitrogen to the soil by the roots, combined with plowing under the rank growth of tops to improve the soil tilth and add humus, it is believed will make the land much more productive.

SUGAR BEETS.

Sugar beets thrive well upon soils strongly impregnated with alkali salts. It is claimed that excess of chlorides in the soil upon which beets are grown, seriously interferes with the crystallization of the sugar in the process of manufacture. This would give no trouble here as only small amounts of chlorides are present and the sulphates do not have the same effect.

As yet we have no sugar factories, but the beets are invaluable as stock food.* Where fattening stock or milch cows are to be fed during the winter, it will pay to raise sugar beets to mix with other food. The beets may be raised upon the alkali part of the farm, but in order to produce large yields the land should be fertilized the same as any other soil upon which beets are to be grown.

In 1897 and 1898 we grew sugar beets upon soil practically free from alkali, and upon soil containing so much alkali that ordinary crops would not grow. The composition of the alkali as shown by analysis made by Mr.

*See Wyoming Station Bulletin No. 30, "Stock Feeding at Lander."

Fairfield in the spring of 1897 was Sodium and Potassium Chlorides 14.39%, Sodium Sulphate 50.16%, Magnesium Sulphate 20.03%, and Calcium Sulphate 15.41%. (Bulletin No. 29, p. 228). The soil was not fertilized in either case and the yield was much larger on the alkali soil. In 1897 the beets were analyzed by the U. S. Department of Agriculture, showing a large percent of sugar and high purity. The results are given in the following table:

Sugar Beets at Laramie.

Year.	Kind of Land.	Yield Per Acre, Pounds.	Sugar in Beet, Percent.	Purity
1897	Without alkali	11,643	19.0	89.2
	Strong alkali	14,486	19.7	88.1
1898	Without alkali	5,985	17.5	88.1
	Strong alkali	12,632	17.5	88.1

RECLAMATION OF ALKALI SOILS.

The old saying that "an ounce of prevention is worth a pound of cure" is in place here. While it may be impossible to prevent the accumulation and rise of alkali on certain portions of the farm, by taking the matter in hand early the time of land becoming unproductive may often be almost indefinitely postponed. The low ground where it is expected alkali will first come to the surface should be kept in some crop, as alfalfa, which will shade the ground the greater part of the time, or planted to such crops as can be thoroughly cultivated to loosen the surface and prevent evaporation.

The only experiments we have made in reclaiming have been by open ditch draining at Sheridan. In the summer of 1895 one hundred and fifty rods of open ditch were dug to drain about ten acres of the north-west corner of the farm. The soil of the farm is underlaid with hardpan and the leachings of alkali from the higher land followed along this hardpan to the lowest part, where the salts came to the surface.

A part of the time the water level was as high as, or above the surface of the ground, and so much alkali collected there that even weeds which ordinarily thrive in the presence of such salts would not grow. In 1896, one hundred and twenty rods of additional ditch, two feet deep, was dug. The following extracts from the annual reports of Superintendent Lewis since 1895 indicate with what success the ditches have aided in reclaiming the land.

Extract from Report of 1895: "Our one hundred and fifty rods of ditch made during the summer will, I think, prove a great benefit to the alkali land. The water does not stand on the surface as it did."

Report of 1896: "Have made one hundred and twenty rods of new ditch, connecting with ditch made during 1895, which is doing much good in reclaiming the alkali land."

Report of 1897: "I consider our experiment with drain ditches has done and will do a great amount of good in reclaiming the land. Land that has been a white, smooth alkali bed for the last three years is now all covered with a heavy growth of weeds and grass, there being but little alkali which is apparent to the passer-by."

EFFECTS OF DIFFERENT ALKALI SALTS ON SEED GERMINATION.

As a continuance of the laboratory work on seed germination begun in 1896 and reported in Bulletin No. 29, Mr. W. H. Fairfield planned and carried out quite an extensive experiment to show the comparative effects of the different alkali salts. The credit for this experiment, the careful manner in which it was carried out and the full notes and tabulations of the results belong wholly to Mr. Fairfield, a large part of whose time was devoted to an enthusiastic study of the matter in hand. The experiment was finished in March of the present year and resulted in data of much interest and

value. In order to substantiate the results obtained, a part of the experiment was repeated in November to check the results by bringing the seeds into contact with the alkali solutions in a different way. The general results of the check are so close to those in the original investigation that they lead to the same conclusions.

It is not our purpose here to make a full report of the experiment or a technical discussion of the results. There are some points of interest and value to the general reader, however, which we wish to note briefly. It is expected the full report of the work with diagrams and tables will be published in the annual report.

Seeds of wheat and rye were germinated in pure water and in solutions of carbonate of soda (black alkali), chloride of soda (common salt), sulphate of soda (glauber salt), sulphate of magnesia (epsom salt), and in sugar syrups the strength of which varied in the same percents as those of the salts used. Each of the salts used and the sugar were applied to the seeds in strengths of one tenth of one percent, four tenths of one percent, seven tenths of one percent, one, two, three, four, five, seven, and nine percent solutions. The sugar was used to throw light upon a technical point, which had been suggested by Professor Slosson, whether the retarding effect was due to the osmotic pressures exerted by the different salt solutions. The experiments show that this is the case and the fact throws much light upon the manner in which the injury to seed germination or plant growth takes place.

In these experiments it has been a most notable fact that small amounts of alkali salts are beneficial or at least that they accelerate instead of retard germination. No doubt small amounts present in the soil also assist in the life of the plant, either stimulating its growth or acting directly as plant food.

The following table shows the amount of salts which may be present without retarding the germination of wheat and rye seeds. It is true that larger amounts than this, while they retarded the germination the first few days, caused the seed to germinate even faster than they did in water, after the third to the fifth day, but in each case the total number of seeds which would germinate was less than where no salt was present.

	Magnesium Sulphate.		Sodium Sulphate.		Sodium Chloride.		Sodium Carbonate.	
	In Solution.	In Soil.	In Solution.	In Soil.	In Solution.	In Soil.	In Solution.	In Soil.
Wheat..	1 0	0.25	0.7	6 17	0.4	0.1	0.4	0.1
Rye . . .	1.0	0.25	0.7	0.17	0.4	0.1	0.1	0.02

The salts are injurious in the order they are given in this table. The black alkali (sodium carbonate) is much more injurious than the other salts, because it has a corroding effect due to the fact that it is not a neutral salt and free acid is present to produce a share of the damage. Of the salts composing our common white alkali magnesium sulphate seems to be the least injurious, while common salt (sodium chloride) is most injurious. Fortunately there is very little sodium chloride associated with the sulphates of soda and magnesia in our alkali. It should be explained that the percent of salt in solution and the percent in the soil may be very different under natural conditions. For example, there may be a large amount of dry salt present. Unless it is in solution it cannot effect the plant for the dry crystals cannot enter the seed or plant and must remain inert until, in the presence of water, they are dissolved. The percent of salt in the soil given above is estimated upon the basis of 24.5% of moisture being present. Thus, if there was 2.20% of salt in the soil, if 24.5% of moisture were present and dissolved all of this salt there would be a nine percent solution of salt to produce its effect upon the seed or plant.

It has been found that fewer seeds will live and it takes longer for them to germinate as the strength of the solution increases and there is a marked difference between the different salts.

Eighty-eight percent of the seeds of wheat germinated in water. In three percent solutions of the salts, amounting to nearly three-fourths of one percent of salt in the soil the following percent of the wheat was germinated: Magnesium sulphate, 86%, sodium sulphate 70%, sodium chloride 35%, sodium carbonate 14%. Ninety-six percent of the rye germinated in water. In three percent solutions of the salts the following percent of rye germinated: Magnesium sulphate 92%, sodium sulphate 56%, sodium chloride 38%, sodium carbonate 22%. This would indicate that rye will stand stronger alkali than will wheat, which corresponds with our results published in Bulletin No. 29.

In addition to the tests upon seed germination quite an extensive experiment was conducted with alkali in pots. Because of conditions which it was difficult to control, we were not able to draw conclusions which would be authentic regarding the effect of these salts upon the plant growth, but the effect of the salt solutions upon the evaporation of water from soil is of interest. That alkali salts have an appreciable effect upon the character of the soil (especially so in the case of black alkali) was long ago pointed out by Professor Hilgard. Everyone who has given any attention to alkali soils has probably noticed that they appear damp, when adjoining lands may seem perfectly dry. In the following table the number of cubic centimeters of water evaporated each day from pots of the same size and containing the same amount of soil, are given. The amounts given are averages of the amounts of water added each day for the first ten days to take place of that lost by evaporation. For the first ten days there were no plants in the pots to tran-

spire water and change the result. There are many irregularities in the table, probably due to difference in the pots themselves, but the general result is the same. From the pots containing no alkali 17.7 c. c. were evaporated each day, while the amounts of water lost from those pots containing 9 % solutions (equivalent to 2.2% alkali in soil with 24.5% moisture) was approximately one half as much.

Influence of Alkali Salts on Evaporation of Water from Pots.

c. c. of water evaporated per day.

SALT.	Per- cent. 0	Per- cent. 0.1	Per- cent. 0.4	Per- cent. 0.7	Per- cent. 1.0	Per- cent. 2.0	Per- cent. 3.0	Per- cent. 4.0	Per- cent. 5.0	Per- cent. 7.0	Per- cent. 9.0
	c. c.	c. c.	c. c.	c. c.	c. c.	c. c.	c. c.	c. c.	c. c.	c. c.	c. c.
Water lost in c. c.	17.7										
Sodium Carbonate.	17.7	17.5	14.7	13.8	12.1	12.6	13.1	*8.2	10.3	10.4	*8.5
Sodium Chloride.	17.7	15.4	14.1	14.0	12.3	10.9	9.7	9.5	7.9	8.9	8.5
Sodium Sulphate.	17.7	18.1	15.0	10.7	16.9	12.5	10.9	7.3	8.2	10.1	9.6
Magnesium Sulphate.	17.7	17.4	13.1	11.4	13.1	11.4	9.2	11.3	8.4	8.2	6.5
Sugar.	17.7	11.1	15.4	13.6	12.9	12.4	10.2	10.1	9.7	9.4	8.8

*Average for 9 days.



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